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INVENTION: CRYSTALLINE SUPERFINE PARTICLES, COMPLEX MATERIAL, METHOD OF MANUFACTURING CRYSTALLINE SUPERFINE PARTICLES, INVERTED MICELLES, INVERTED MICELLES ENVELOPING PRECURSOR SUPERFINE PARTICLES, INVERTED MICELLES ENVELOPING CRYSTALLINE SUPERFINE PARTICLES, AND PRECURSOR SUPERFINE PARTICLES

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Sir:

CERTIFIED TRANSLATION

Yuka NAKAMURA residing at c/o SUGIURA PATENT OFFICE, 7th floor, Ikebukuro Park Bldg., 49-7, Minami Ikebukuro 2-chome, Toshima-ku, Tokyo, JAPAN, declares:

(1) that she knows well both the Japanese and English languages;

(2) that she translated Japanese Application No. 2003-149921 from Japanese to English;

(3) that the attached English translation is a true and correct translation of the above-identified Japanese Application to the best of her knowledge and belief; and

(4) that all statements made of her own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements are made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 USC 1001, and that such false statements may jeopardize the validity of the application or any patent issuing thereon.

February 3, 2006 — Yuka Nakamura

Date — Yuka NAKAMURA

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[Title of the Invention] Stress Emission Material and Complex Material

[Scope of Claims for a Patent]

[Claim 1]

A stress emission material characterized in having the composition expressed by:

$Sr_pEu_qLa_rAl_2O_{4-s}$

where $p+q+r=1$

$0.8<p<1$

$0<q<0.2$

$0<r<0.2$ and

$-0.1<s<0.2$

[Claim 2]

A stress emission material characterized in containing at least Eu and La added to a material expressed by:

$Sr_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$ and

$0\leq y<0.2$

[Claim 3]

The stress emission material according to claim 2 wherein the total amount of Eu and La added in the stress emission material is from 0.002% to 30% in mol % relative to Sr.

[Claim 4]

The stress emission material according to claim

2 wherein each of Eu and La is added in the stress emission material by an amount from 0.001% to 20% in mol % relative to Sr.

[Claim 5]

A stress emission material characterized in containing at least Eu and any of Ce, Er, La and Tm added to a material expressed by:

$Sr_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$ and

$0\leq y<0.2$

[Claim 6]

A stress emission material characterized in containing at least Eu and any of Ce, Er, La, Tm, Gd, Lu and Yb added to a material expressed by:

$Sr_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$ and

$0\leq y<0.2$

[Claim 7]

A stress emission material characterized in containing at least Eu and La added to a material expressed by:

$M_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$

$0\leq y<0.2$ and

$M=Sr_kBa_lCa_mMg_n$

$(0\leq k,\ l,\ m,\ n\leq 1,\ k+l+m+n=1)$

[Claim 8]

The stress emission material according to claim 7 wherein the total amount of Eu and La added in the stress emission material is from 0.002% to 30% in mol % relative to M.

[Claim 9]

The stress emission material according to claim 7 wherein the amount of Eu and the amount of La added in the stress emission material are each from 0.001% to 20% in mol % relative to M.

[Claim 10]

A stress emission material characterized in containing at least Eu and any of Ce, Er, La and Tm added to a material expressed by:

$M_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$

$0\leq y<0.2$ and

$M=Sr_kBa_lCa_mMg_n$

$(0\leq k,\ l,\ m,\ n\leq 1,\ k+l+m+n=1)$

[Claim 11]

A stress emission material characterized in containing at least Eu and any of Ce, Er, La, Tm, Gd, Lu and Yb added to a material expressed by:

$M_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$

$0\leq y<0.2$ and

$M=Sr_kBa_lCa_mMg_n$

$(0\leq k,\ l,\ m,\ n\leq 1,\ k+l+m+n=1)$

[Claim 12]

A complex material comprising a stress emission material and another material, the stress emission material having the composition expressed by:

$Sr_pEu_qLa_rAl_2O_{4-s}$

where $p+q+r=1$

$0.8<p<1$

$0<q<0.2$

$0<r<0.2$ and

$-0.1<s<0.2$

[Claim 13]

A complex material comprising a stress emission material and another material, the stress emission material containing at least Eu and La added to a material expressed by:

$Sr_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$ and

$0\le y<0.2$

[Claim 14]

The complex material according to claim 13 wherein the other material is a transparent material.

[Claim 15]

The complex material according to claim 13 wherein the other material is a resin.

[Claim 16]

A complex material comprising a stress emission material and another material, the stress emission material

containing at least Eu and any of Ce, Er, La and Tm added to a material expressed by:

$Sr_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$ and

$0\leq y<0.2$

[Claim 17]

A complex material comprising a stress emission material and another material, the stress emission material containing at least Eu and any of Ce, Er, La, Tm, Gd, Lu and Yb added to a material expressed by:

$Sr_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$ and

$0\leq y<0.2$

[Claim 18]

A complex material comprising a stress emission material and another material, the stress emission material containing at least Eu and La added to a material expressed by:

$M_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$

$0\leq y<0.2$ and

$M=Sr_kBa_lCa_mMg_n$

$(0\leq k,\ l,\ m,\ n\leq 1,\ k+l+m+n=1)$

[Claim 19]

A complex material comprising a stress emission material and another material, the stress emission material containing at least Eu and any of Ce, Er, La and Tm added

to a material expressed by:

$M_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$

$0\leq y<0.2$ and

$M=Sr_kBa_lCa_mMg_n$

$(0\leq k, l, m, n\leq 1, k+l+m+n=1)$

[Claim 20]

A complex material comprising a stress emission material and another material, the stress emission material containing at least Eu and any of Ce, Er, La, Tm, Gd, Lu and Yb added to a material expressed by:

$M_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$

$0\leq y<0.2$ and

$M=Sr_kBa_lCa_mMg_n$

$(0\leq k, l, m, n\leq 1, k+l+m+n=1)$

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention belongs]

The present invention relates to a stress emission material and a complex material that are suitable for use in manufacture of a complex material used in, for example, the field of entertainment, the field of amusement or the field of optics.

[0002]

[Prior Art]

For years, aluminate compound materials doped

with rare earth elements have been remarked as fluorescent materials, and have been under vigorous researches. Among various aluminate compound materials, Eu-doped strontium aluminate, $SrAl_2O_4$ (written as $SrAl_2O_4$:Eu herein below) has attracted the greatest attention as from a report on the phenomenon of stress emission as introduced later. Thus, prehistory of researches and developments of this $SrAl_2O_4$:Eu is first explained below while citing prior art documents.

[0003]

History of patents and researches of $SrAl_2O_4$:Eu as fluorescent material

$SrAl_2O_4$:Eu has the prehistory of having been studied as a fluorescent material from a long time ago. The following patent on this material issued already in the 1960s, and the material is currently one of known materials.

[Patent Document 1]

Specification of U.S. Patent No. 3294699

[0004]

History of inventions and researches of phosphorescent material/long-afterglow phosphor $SrAl_2O_4$:Eu+Dy (under the brand of "LumiNova") by Nemoto & Co., Ltd.

There are many reports and commentaries on this phosphor (for example, Non-patent Document 1, Patent Documents 2 and 3). In Patent Document 3, phosphorescent material composed of $SrAl_2O_4$:Eu+La is disclosed.

[Non-patent Document 1]

T. Matsuzawa, Y. Aoki, T. Takeuchi and Y. Murayama, J.

Electrochem. Soc., 143(1996)2670-2673

[Patent Document 2]

Specification of Japanese Patent No. 2543825

[Patent Document 3]

Japanese Patent Laid-open Publication JP-H7-11250-A

[0005]

Pioneer researches of friction emission material

Friction emission has been studied for over ten years, and patent applications on the friction emission were filed (see Patent Documents 4 and 5). Patent Document 4 is an invention by Yamada et al. of HITACHI, LTD., and discloses friction emission of strontium aluminate doped with bivalent Eu. The Patent Document 4 was the first document on the friction emission of strontium aluminate as far as the present inventors know. Patent Document 5 is an invention by Tsuda et al. of Toshiba Corporation, and discloses inorganic materials (such as ZnS:Mn, or the like) that emits light under friction.

[Patent Document 4]

Japanese Patent Laid-open Publication JP-S48-46582-A

[Patent Document 5]

Japanese Patent Laid-open Publication JP-H2-38484-A

[0006]

Stress emission in $SrAl_2O_4$:Eu compound materials by C-N. Xu, et al. of National Institute of Advanced Industrial Science and Technology (AIST), Institute for Structural and Engineering Materials (ISEM), Multifunctional Materials

Technology Group as well as history of researches

There are many commentaries and reports on the stress emission $SrAl_2O_4$:Eu compound materials and related substances (for example, Non-patent Documents 6-10). Patent Document 6 discloses materials that contain transition elements or rare earth elements having electron shells of 3d, 4d, 5d and 4f added to $MgAl_2O_4$, $CaAl_2O_4$, Al_2O_3 and $SrMgAl_{10}O_{17}$ as their matrices and emit light upon deformation with a mechanical external force, as well as a manufacturing method thereof. Patent Document 7 discloses materials containing transition elements or rare earths added to matrix materials of $Sr_3Al_2O_6$ and $Ga_3Al_2O_6$, as well as a manufacturing method thereof by baking under a controlled amount of the additive substance in 0.01 to 20 weight percent in a reducing atmosphere adjusted to 800 to 1700°C. Document 8 describes materials that contain regulated aluminate having a non-stoichiometrical composition and emit light under mechanical energy. Patent Document 9 discloses materials MN_2O_4, where M=Mg, Sr, Ba or Zn, N=Ga or Al, doped with rare earths or transition metals as their emission centers, together with a manufacturing method thereof. Document 10 discloses a method for increasing emission intensity of stress emission materials using aluminum alcoholate for compounding stress emission aluminate.

[Patent Document 6]

Specification of Japanese Patent No. 3136340

[Patent Document 7]

Specification of Japanese Patent No. 2992631

[Patent Document 8]

Japanese Patent Laid-open Publication JP-2001-49251-A

[Patent Document 9]

Japanese Patent Laid-open Publication JP-2002-194349-A

[Patent Document 10]

Japanese Patent Laid-open Publication JP-2002-220587-A

[0007]

Recently, Akiyama and Xu et al. reported on the influence of the composition of strontium aluminate doped with Eu and Dy on intensity of mechanoluminescence (Non-patent Document 2).

[Non-patent Document 2]

M. Akiyama, C-N. Xu, Y. Liu, K. Nonaka, and T. Watanabe, J. Luminescence 97(2002)13-18

[0008]

In addition, there is a report on synthesis of $SrAl_2O_4$ compound materials and measurement result of X-ray diffraction (Non-patent Document 3).

[Non-patent Document 3]

F. Hanaic, T. Y. Chemekova and J. Majling, J. Appl. Phys., 12(1979)243

[0009]

[Subject that the Invention is to solve]

In any of the above-introduced prior art techniques, the stress emission material may be applied to

a sensor, for example. However, emission intensity of the stress emission material is not enough for the use that requires a person to watch emission of light, such as the use for entertainment that emission of light is induced by a hand or finger touch of a person, or the like. Accordingly, it would be desirable to improve emission intensity.

[0010]

The present invention intends to overcome the above-mentioned problem.

That is, an object of the invention is to provide a new stress emission material whose emission intensity is higher than that of known stress emission materials.

Another object of the invention is to provide a complex material from which a hand or finger touch of a person can induce emission of light and which is allowed to emit light in high intensity only when a stress is applied by a hand touch, for example.

The above-described objects and other objects will be more apparent from the following description taken in conjunction with the accompanying drawings.

[0011]

[Means for Solving the Subject]

Through vigorous studies toward solution of the aforementioned problems involved in the prior art techniques, the inventors have found new materials different from known materials such as the stress emission material prepared by adding only europium (Eu) to aluminate (Patent Documents

4, 6-10) and the stress emission material prepared by adding Eu and dysprosium (Dy) ($SrAl_2O_4$:Eu, Dy) (Non-patent Document 2). Unlike the stress emission material made by adding Eu to aluminate, these new materials are prepared by lanthanum (La), cerium (Ce), erbium (Er), thulium (Tm), gadolinium (Gd) lutetium (Lu) or ytterbium (Yb) as the second additive element. Among these new materials, those containing La, Ce, Er or Tm in addition to Eu ensure very intensive emission as compared with those known stress emission materials. Especially, the novel stress emission material containing La in addition to Eu ensures remarkably high emission intensity.

The inventors have reached the present invention based on the aforementioned studies.

[0012]

The first aspect of the present invention is a stress material characterized in having the composition expressed by:

$Sr_pEu_qLa_rAl_2O_{4-s}$

where $p+q+r=1$

$0.8<p<1$

$0<q<0.2$

$0<r<0.2$ and

$-0.1<s<0.2$

The second aspect of the present invention is a stress emission material characterized in containing at least Eu and La added to a material expressed by:

$Sr_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$ and

$0 \leq y<0.2$

[0013]

The total amount of Eu and La added in the stress emission material is typically from 0.002% to 30% in mol % relative to Sr. Alternatively, each of Eu and La is added in the stress emission material typically by an amount from 0.001% to 20% in mol % relative to Sr.

[0014]

The third aspect of the present invention is a stress emission material characterized in containing at least Eu and any of Ce, Er, La and Tm added to a material expressed by:

$Sr_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$ and

$0 \leq y<0.2$

[0015]

The total amount of Eu and any of Ce, Er, La and Tm added in the stress emission material is typically from 0.002% to 30% in mol % relative to Sr. Alternatively, the amount of Eu and the amount of Ce, Er, La or Tm added in the stress emission material are each typically from 0.001% to 20% in mol % relative to Sr.

[0016]

The fourth aspect of the present invention is a stress emission material characterized in containing at

least Eu and any of Ce, Er, La, Tm, Gd, Lu and Yb added to a material expressed by:

$Sr_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$ and

$0\leq y<0.2$

[0017]

The total amount of Eu and any of Ce, Er, La, Tm, Gd, Lu and Yb added in the stress emission material is typically from 0.002% to 30% in mol % relative to Sr. Alternatively, the amount of Eu and the amount of Ce, Er, La, Tm, Gd, Lu or Yb added in the stress emission material are each typically from 0.001% to 20% in mol % relative to Sr.

[0018]

The fifth aspect of the present invention is a stress emission material characterized in containing at least Eu and La added to a material expressed by:

$M_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$

$0\leq y<0.2$ and

$M=Sr_kBa_lCa_mMg_n$

$(0\leq k,\ l,\ m,\ n\leq 1,\ k+l+m+n=1)$

[0019]

The total amount of Eu and La added in the stress emission material is typically from 0.002% to 30% in mol % relative to M. Alternatively, the amount of Eu and the amount of La added in the stress emission material are each typically

from 0.001% to 20% in mol % relative to M.

[0020]

The sixth aspect of the present invention is a stress emission material characterized in containing at least Eu and any of Ce, Er, La and Tm added to a material expressed by:

$M_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$

$0\leq y<0.2$ and

$M=Sr_kBa_lCa_mMg_n$

$(0\leq k,\ l,\ m,\ n\leq 1,\ k+l+m+n=1)$

[0021]

The total amount of Eu and any of Ce, Er, La and Tm added in the stress emission material is typically from 0.002% to 30% in mol % relative to M. Alternatively, the amount of Eu and the amount of Ce, Er, La or Tm added in the stress emission material are each typically from 0.001% to 20% in mol % relative to M.

[0022]

The seventh aspect of the present invention is a stress emission material characterized in containing at least Eu and any of Ce, Er, La, Tm, Gd, Lu and Yb added to a material expressed by:

$M_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$

$0\leq y<0.2$ and

$M=Sr_kBa_lCa_mMg_n$

$(0 \leq k, l, m, n \leq 1, k+l+m+n=1)$

[0023]

The total amount of Eu and any of Ce, Er, La, Tm, Gd, Lu and Yb added in the stress emission material is typically from 0.002% to 30% in mol % relative to M. Alternatively, the amount of Eu and the amount of Ce, Er, La, Tm, Gd, Lu or Yb added in the stress emission material are each typically from 0.001% to 20% in mol % relative to M.

[0024]

In the fifth to seventh aspects of the present invention, M in $M_{1-x}Al_2O_{4-x-y}$ is expressed as $Sr_kBa_lCa_mMg_n$. This means that it is a solid solution containing alkaline earths Sr, Ba, Ca and Mg in any composition.

[0025]

According to the second to seventh aspects of the present invention, stress emission materials contain Eu and any of Ce, Er, La, Tm, Gd, Lu and Yb added to a material expressed by $Sr_{1-x}Al_2O_{4-x-y}$ or $M_{1-x}Al_2O_{4-x-y}$. However, stress emission materials will be obtained as well by adding other rare earth elements instead of Ce, Er, La, Tm, Gd, Lu or Yb, such as scandium (Sc), yttrium (Y), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), terbium (Tb) or holmium (Ho). According to the second to seventh aspects of the present invention, all of the stress emission materials contain Eu as an additive element. However, containment of Eu is not considered the absolute requirement.

Instead, stress emission materials will be obtained by adding two different kinds of rare earth elements not including Eu. Furthermore, stress emission materials will be obtained as well by adding at least one kind of rare earth element and at least one kind of transition metal element.

[0026]

The eighth aspect of the present invention is a complex material comprising a stress emission material and another material, the stress emission material having the composition expressed by:

$Sr_pEu_qLa_rAl_2O_{4-s}$

where $p+q+r=1$

$0.8<p<1$

$0<q<0.2$

$0<r<0.2$ and

$-0.1<s<0.2$

The ninth aspect of the present invention is a complex material comprising a stress emission material and another material, the stress emission material containing at least Eu and La added to a material expressed by:

$Sr_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$ and

$0\le y<0.2$

[0027]

The tenth aspect of the present invention is a complex material comprising a stress emission material and another material, the stress emission material containing

at least Eu and any of Ce, Er, La and Tm added to a material expressed by:

$Sr_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$ and

$0\leq y<0.2$

[0028]

The eleventh aspect of the present invention is a complex material comprising a stress emission material and another material, the stress emission material containing at least Eu and any of Ce, Er, La, Tm, Gd, Lu and Yb added to a material expressed by:

$Sr_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$ and

$0\leq y<0.2$

[0029]

The twelfth aspect of the present invention is a complex material comprising a stress emission material and another material, the stress emission material containing at least Eu and La added to a material expressed by:

$M_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$

$0\leq y<0.2$ and

$M=Sr_kBa_lCa_mMg_n$

$(0\leq k,\ l,\ m,\ n\leq 1,\ k+l+m+n=1)$

[0030]

The thirteenth aspect of the present invention

is a complex material comprising a stress emission material and another material, the stress emission material containing at least Eu and any of Ce, Er, La and Tm added to a material expressed by:

$$M_{1-x}Al_2O_{4-x-y}$$

where $-0.3<x<0.3$

$0\le y<0.2$ and

$M=Sr_kBa_lCa_mMg_n$

$(0\le k,\ l,\ m,\ n\le 1,\ k+l+m+n=1)$

[0031]

The fourteenth aspect of the present invention is a complex material comprising a stress emission material and another material, the stress emission material containing at least Eu and any of Ce, Er, La, Tm, Gd, Lu and Yb added to a material expressed by:

$$M_{1-x}Al_2O_{4-x-y}$$

where $-0.3<x<0.3$

$0\le y<0.2$ and

$M=Sr_kBa_lCa_mMg_n$

$(0\le k,\ l,\ m,\ n\le 1,\ k+l+m+n=1)$

[0032]

In the eighth to fourteenth aspects of the present invention, the material to be complexed with the stress emission materials may be selected from various kinds of materials, depending on the intended use. The material may be only one kind or a combination of two or more kinds of different materials. Alternatively, it may be one or both

of an organic material or an inorganic material. In some cases, the material may be an organic/inorganic complexed substance. For example, this material may be one of various kinds of resins and glass. If the complex material should be flexible, an elastic material is selected from those materials. In this case, weight percentage of the stress emission materials in the complex material may be determined adequately depending upon the intended use of the complex material. However, if an elastic material is used as the material to be complexed with the stress emission material, the weight percent is preferably controlled in the range from 30% and to less than 100%, or more preferably from 30% to 80%, from the standpoint of keeping the entirety of the complex material flexible to facilitate stress emission with human force and improve the durability. Those materials may have any Young's modulus as far as human force, for example, can readily induce emission of light. Young's modulus of a relatively hard material will be, for example, 10 MPa or more, and that of a softer material is preferably smaller than 10 MPa, or preferably not larger than 1 MPa, for example. Usually, it is 0.0001 MPa or more. Similarly, Young's modulus of the complex material is 10 MPa or more, for example. Young's modulus of a softer complex material is, for example, smaller than 10 MPa, or typically not larger than 1 MPa, for example. Usually, it is 0.0001 MPa or more.

[0033]

When complexing with other materials, a form of

the stress emission material is typically a fine particle. The fine particles may have any shapes such as spherical, cubic, rectangular, flat or rod-like shapes. In this case, in the complex material, the fine particles composed of the stress emission materials disperse without contacting with other materials.

[0034]

A typical material complexed with the stress emission material is an organic substance. For example, it is at least one kind of substances selected from the group consisting of its examples are acrylic resin, methacrylic resin, polymethyl methacrylate, ABS resin, polycarbonate, polystyrene, polyethylene, polypropylene, polyacetal, urethane resin, polyester, epoxy resin, silicone rubber, organic silicon compounds having siloxane bonds and organic piezoelectric substances. Examples of organic piezoelectric substances are polyvinylidene fluoride (PVDF) and polytrifluoroethylene copolymers. In addition to them, foaming substances such as expanded polystyrene, polyethylene foam and their mixture are usable, and they are especially suitable for obtaining a soft complex material excellent in elasticity.

[0035]

In case an external force is applied to a complex material made by complexing the crystalline ultrafine particles with a resin such as polymethyl methacrylate, ABS resin, polycarbonate, polystyrene, polyethylene,

polypropylene, polyacetal, urethane resin, polyester, epoxy resin, silicone rubber, organic silicon compounds having siloxane bonds or organic piezoelectric substances that are mentioned above, the complex material elastically yields without losing the original property of the resin. Accordingly, a stress is generated in the dispersed crystalline ultrafine particles, and emission of light from the crystalline ultrafine particles can be confirmed. In this case, a force of a light hand touch of a person is sufficient as the external force deform the complex material and give rise to stress emission thereof.

[0036]

When preparing the complex material combining a resin and fine particles composed of the stress emission materials, a photo-curing resin may be selected as the resin. Thus, a structure having a complicate conformation can be made by making use of a three-dimensional optical molding method. This photo-curing resin is mainly composed of a pre-polymer, monomer and initiator. For example, epoxy-based, acrylic, en-thiol-based resins are usable as the photo-curing resin.

[0037]

Alternatively, the material to be complexed with the fine particles composed of the stress emission materials may be an electrically conductive organic substance that deforms by acquiring ions, for example. Examples of such electrically conductive organic substances are

electrically conductive polymers of complex aromatic rings such as polypyrole, polythiophene, and polyanilin. Polymeric gel materials are also usable as the material to be complexed with the fine particles. When a polymeric gel material is used, it may be at least one kind of materials selected from the group consisting of water-soluble non-electrolytic polymeric gel having a thermal displacement function, electrolytic polymeric gel giving rise to displacement by pH, combination of a polymeric compound giving rise to displacement by electricity and a surface-active agent, polyvinyl alcohol-based material and polypyrrolic material. The water-soluble non-electrolytic polymeric gel displaceable with heat may be, for example, polyvinyl methyl ether or poly-N-isopropyl acrylamide. The electrolytic polymeric gel displaceable with pH may be, for example, polyacrylonitrile. The polymeric compound displaceable with electricity may be, for example, polyacrylamide-2-methylpropane sulforic acid.

[0038]

In case an inorganic substance is used as the material to be complexed with the fine particles composed of the stress emission materials in the complex material, inorganic glass is typically used as an inorganic substance. In general, this glass contains at least one kind of element selected from the group consisting of Si, Ge, Ti, Zr, Pb, B, Al, P, As, Mg, Ca, Sr, Ba, Li, Na, K, S, Se, Te and F. More specifically, it is composed of at least one kind of

substance selected from an oxide containing Si, Al, Ti or B, silica glass, borosilicate glass, boric acid glass, soda glass and aluminate-based glass. These kinds of glass have higher Young's modulus than resins. So much, however, they are advantageous inducing a stress in the fine particles more effectively.

[0039]

In case the complex material is a liquid paint, ink, adhesive, or the like, a binder, additive, solvent, or the like, is typically used as another materials to be complexed with the fine particles. An inorganic resin (such as polysiloxane or polyborosiloxane), metallic alcoxide (such as organic silicate or organic titanate), both as a binder; viscosity improver, anti-sedimentation agent or hardener, all as an additive; organic solvent or water, both as a solvent; is selected adequately where necessary.

[0040]

Specific examples of the complex material are: a combination of fine particles made of $SrAl_2O_4$:Eu, La, and an organic substance as the other material comprising polyester, acrylic resin, methacryl resin or their mixture; a combination of fine particles made of $SrAl_2O_4$:Eu, La, and an inorganic material as the other material comprising inorganic glass.

[0041]

Various kinds of structures can be manufactured from the complex material. Artificial light-emitting

sheets, artificial light-emitting hair and artificial light-emitting fiber are possible examples. Further, artificial light-emitting hair structures, artificial light-emitting skin, artificial light-emitting bodies can be made from such artificial light-emitting hair or artificial light-emitting fiber.

[0042]

More specifically, it is possible to manufacture artificial light-emitting hair structure having a conformation in which a plurality of artificial light-emitting hairs composed of the complex material are fixed upright on a substratum, artificial light-emitting skin, and artificial light-emitting body having a conformation in which a plurality of artificial light-emitting hairs composed of the complex material are fixed upright on a body surface. The artificial light-emitting hair typically has a needle-like, fiber-like, or thread-like shape. Thickness of the artificial light-emitting hair may be determined as desired provided it sufficiently bends when touched by hands or fingers of a person and reliably emits light. However, if the artificial light-emitting hair is desired to be flexible, reliably undergo internal stress required for stress emission and thereby emit light easily, and gives favorable tactile impression to a person who touches it, the thickness is preferably controlled to be not thicker than 2 mm, more preferably not thicker than 1 mm, or still more preferably

not thicker than 0.5 mm. The lower limit of the thickness of the artificial light-emitting hair is normally 0.1 mm or more, for example, although it may be determined as desired as far as sufficient strength is ensured. The thickness may be uniform in the entire area of the substratum, or may be different locally. Surface density of the artificial light-emitting hair on the substratum may be determined according to need. However, in order to ensure clear emission of light from the location a human hand or finger touches, the surface density is preferably controlled to be one per cm^2, or more preferably two per cm^2. The upper limit of the surface density is determined by the thickness of the artificial light-emitting hair used. The surface density may be uniform throughout the entire area of the substratum, or may be different locally. Standing angle of the artificial light-emitting hair relative to the substratum is determined according to need. It may be either 90° or any other angle. Typically, however, it is 90°. This angle may be uniform throughout the entire area of the substratum, or may be different locally. For fixing the artificial light-emitting hair upright on the substratum, any appropriate method may be used essentially. Typically, however, roots of artificial light-emitting hairs are held in holes (either through holes or blind holes) formed in the substratum. The artificial light-emitting hairs are typically aligned at periodical intervals. For example, they are aligned in a regular grid pattern such as a square

grid pattern or an equilateral triangular pattern. The pattern of alignment may be uniform throughout the entire area of the substratum, or may be different locally. Artificial hairs not having the light-emitting function may be mixed among the artificial light-emitting hairs if so desired.

[0043]

To ensure uniform emission from the artificial light-emitting hair, the fine particles are preferably dispersed uniformly in the artificial light-emitting hair. To improve the tactile impression of the artificial light-emitting hair or enhance its durability, the artificial light-emitting hair is surface-coated by an organic material layer such as a coating layer. The substratum is preferably made of a flexible material permitting a human hand force to bend it easily. However, any other material may be used as well.

[0044]

Artificial light-emitting fabric can be manufactured from artificial light-emitting fibers of the complex material. The weaving or knitting cycle of the artificial light-emitting fabric is determined depending upon the intended use. To ensure clear emission just from a portion touched by a human hand, for example, the cycle is preferably once per cm or more, or more preferably twice per cm or more. There are various types of weaving or knitting configurations, and any of them may be selected

depending upon the intended use. The artificial light-emitting fabric may be made of artificial light-emitting fibers alone. However, it may be weaved or knitted by using a substratum having periodical through holes, for example, and passing artificial light-emitting fibers through the through holes. In this case, a periodical beautiful pattern will be made on the fabric. The surface density of the through holes in the substratum is preferably one per cm^2 or more, or more preferably two per cm^2 or more. If so desired, other fibers not having the light-emitting function may be mixed among the artificial light-emitting fibers.

[0045]

The above-summarized artificial light-emitting hair structures, artificial light-emitting skins, artificial light-emitting bodies and artificial light-emitting fabrics are suitable for use as bodies or decorations of various kinds of robots (working robots, entertainment robots, amusement robots, and so on), various kinds of home electric devices such as audio devices (including loudspeakers), television sets, video devices, etc. as well as daily goods such as stationery goods.

[0046]

In the present invention, to induce stress emission, an external energy is applied to the stress emission materials and the complex materials. This energy is typically a mechanical energy by a stress generated by

an external force. Otherwise, vibration energies by elastic vibrations or acoustic waves such as ultrasonic waves applied from outside are also contemplated herein.

[0047]

The experiment by the inventors confirms that a stress emission material can be obtained by adding Eu and any of La, Ce, Er, Tm, Gd, Lu and Yb to a material expressed by $Sr_{1-x}Al_2O_{4-x-y}$ or $M_{1-x}Al_2O_{4-x-y}$. The inventors have been analyzing how stress emission is induced in those stress emission materials.

[0048]

Further, when artificial light-emitting hair or artificial light-emitting fiber is manufactured from the complex material, the artificial light-emitting hair or the artificial light-emitting fiber is sufficiently bent easily by a light hand or finger touch of a person with soft feeling, thereby inducing emission of light. Furthermore, emission of light stops immediately after removal of the touch. Thus, the user can induce and acknowledge emission of light by giving a light touch to the product, and can feel comfortable with it, or it effectively induce his/her interest.

[0049]

[Embodiment of the Invention]

Some embodiments of the invention will now be explained below with reference to the drawings.

First embodiment

This embodiment is directed to a stress emission

material composed of $SrAl_2O_4$:Eu, La and a complex material prepared by using the stress emission material.

This stress emission material can be manufactured according the following procedure by ordinary solid phase reaction, for example.

First, 0.98 mol of strontium carbonate ($SrCO_3$) of a special grade and 1.00 mol of alumina (Al_2O_3) are prepared, and 0.005 mol of Eu in form of europium oxide (Eu_2O_3) and 0.005 mol of La in form of lanthanum oxide (La_2O_2) are added. Further, 0.08 mol of boron oxide (B_2O_3) is added as a flux. Then, these compounds are mixed in a ball mill. After that, this mixed powder sequentially undergoes calcination in oxygen at 1400°C and annealing for reduction in an N_2 atmosphere added with H_2 (4%) at 1200°C. In this manner, a sample was prepared.

[0050]

Fig. 1 shows an X-ray diffraction pattern of the sample synthesized in this manner. It was confirmed from Fig. 1 that the obtained sample was entirely indexed by the monoclinic system similarly to a known article (Non-patent Document 3) and that the major component was composed of crystals similar to those of the article (Non-patent Document 3).

[0051]

After that, epoxy resin and the powder of $SrAl_2O_4$:Eu, La are blended and mingled by the ratio of 1:1 in weight. The product was shaped in form of a sheet of

several centimeters each side, and left for a whole day. As a result, an inorganic/organic complex sheet was obtained. This sheet was confirmed to be as thin as less than 1 mm (in form of an underlay) and gleam intensively in the dark when slightly bent. In the same manner, a cube of several mm each side was prepared by using a die. Then, a compressing load was applied to this sample from a load applying test machine made by the inventors themselves to generate a stress. The light then generated was spectrally analyzed by a spectrometer, and stress emission spectrum appearing under the compression were measured. Its result is shown in Fig. 2. It will be appreciated from Fig. 2 that broad emission spectrum having the peak near the wavelength of 520 nm was obtained.

[0052]

On the other hand, as a comparative example, a stress emission material made of $SrAl_2O_4$:Eu and a complex material composed of the stress emission material were prepared, and they were measured similarly. The stress emission material was prepared in the same manner as explained above, except that lanthanum oxide is not added to the source material.

Fig. 3 shows an X-ray diffraction pattern of the samples synthesized in this manner. It was confirmed from Fig. 3 that the obtained sample was entirely indexed by the monoclinic system similarly to the known article and that the major component was composed of crystals similar to those

of that article.

[0053]

After that, powder of $SrAl_2O_4$:Eu and epoxy resin were complexed in the same manner, and an inorganic/organic complexed sheet material was prepared. Here again, the sheet was confirmed to be as thin as less than 1 mm and gleam intensively in the dark when slightly bent. In the same manner, a cube of several mm each side was prepared by using a die, and stress emission spectrum appearing under the compression was measured similarly. Its result is shown in Fig. 4. It will be appreciated from Fig. 4 that broad emission spectrum having the peak near the wavelength of 520 nm was obtained similarly to those already reported (Non-patent Document 3).

[0054]

Fig. 5 shows stress emission spectrum of the stress emission material according to the first embodiment and stress emission spectrum of the stress emission material as the comparative example in combination. It is apparent from Fig. 5 that the stress emission intensity of the stress emission material according to the first embodiment is clearly higher than that of the stress emission material as the comparative example. The emission peak near the wavelength of 520 nm is more than three times. Fig. 6 shows emission intensities of the emission peak near the wavelength of 520 nm of the material prepared by adding only Eu to $SrAl_2O_4$ and the material prepared by adding Eu and La, Ce, Er, Tm,

Gd, Lu, Yb or Dy to $SrAl_2O_4$.

[0055]

As explained above, according to the first embodiment, it is possible to obtain $SrAl_2O_4$:Eu, La as a novel stress emission material whose emission intensity is more than three times that of $SrAl_2O_4$:Eu that is a conventional stress emission material. Since the stress emission intensity is much higher than that of the conventional stress emission material, the emission of light is visible to human eyes, for example. Furthermore, if this stress emission material is complexed with a resin, for example, then a user can easily induce emission of light only by lightly touching it with his/her hand, for example. Moreover, it is possible to permit emission only when applying a stress by touching it, for example.

[0056]

Second embodiment

This embodiment is directed to a stress emission material composed of $SrAl_2O_4$:Eu, Ce and a complex material made of the stress emission material.

The stress emission material of this embodiment can be prepared in the same manner as the first embodiment except that cerium oxide (Ce_2O_3) is added as a Ce source instead of a La source.

An X-ray diffraction pattern of the synthesized sample was measured, and it was confirmed that the sample was entirely indexed by the monoclinic system similarly to

the known article (Non-patent Document 3) and that the major component was composed of crystals similar to those of the article (Non-patent Document 3).

[0057]

Similarly to the first embodiment, powder of $SrAl_2O_4$:Eu, Ce was next complexed with epoxy resin, and an inorganic/organic complex sheet material was prepared. This sheet was also confirmed to be as thin as less than 1 mm gleam intensively in the dark when slightly bent. In the same manner, a cube of several mm each side was prepared by using a die, and stress emission spectrum appearing under compression was measured similarly to the first embodiment. As a result, broad emission spectrum having a peak near the wavelength of 520 nm was confirmed. Emission intensity of the emission peak near the wavelength 520 nm was two times or more as compared with that of the sample using $SrAl_2O_4$:Eu (Fig. 6).

[0058]

According to the second embodiment, it is possible to obtain $SrAl_2O_4$:Eu, Ce as a novel stress emission material whose emission intensity is much higher by more than two times of the emission intensity of $SrAl_2O_4$:Eu that is a conventional stress emission material, and it is possible to ensure the same advantages as those of the first embodiment.

[0059]

Third embodiment

This embodiment is directed to a stress emission material composed of $SrAl_2O_4$:Eu, Tm and a complex material made of the stress emission material.

The stress emission material of this embodiment can be prepared in the same manner as the first embodiment except that thulium oxide (Tm_2O_3) is added as a Tm source instead of a La source.

An X-ray diffraction pattern of the synthesized sample was measured, and it was confirmed that the sample was entirely indexed by the monoclinic system similarly to the known article (Non-patent Document 3) and that the major component was composed of crystals similar to those of the article (Non-patent Document 3).

[0060]

Similarly to the first embodiment, powder of $SrAl_2O_4$:Eu, Tm was next complexed with epoxy resin, and an inorganic/organic complex sheet material was prepared. This sheet was also confirmed to be as thin as less than 1 mm and gleam intensively in the dark when slightly bent. In the same manner, a cube of several mm each side was prepared by using a die, and stress emission spectrum appearing under compression was measured similarly to the first embodiment. As a result, broad emission spectrum having a peak near the wavelength of 520 nm was confirmed. Emission intensity of the emission peak near the wavelength 520 nm was two times or more as compared with that of the sample using $SrAl_2O_4$:Eu

(Fig. 6).

[0061]

According to the third embodiment, it is possible to obtain $SrAl_2O_4$:Eu, Tm as a novel stress emission material whose emission intensity is much higher by more than two times of the emission intensity of $SrAl_2O_4$:Eu that is a conventional stress emission material, and it is possible to ensure the same advantages as those of the first embodiment.

[0062]

Fourth embodiment

This embodiment is directed to a stress emission material composed of $SrAl_2O_4$:Eu, Er and a complex material made of the stress emission material.

The stress emission material of this embodiment can be prepared in the same manner as the first embodiment except that erbium oxide (Er_2O_3) is added as an Er source instead of a La source.

An X-ray diffraction pattern of the synthesized sample was measured, and it was confirmed that the sample was entirely indexed by the monoclinic system similarly to the known article (Non-patent Document 3) and that the major component was composed of crystals similar to those of the article (Non-patent Document 3).

[0063]

Similarly to the first embodiment, powder of $SrAl_2O_4$:Eu, Er was next complexed with epoxy resin, and an

inorganic/organic complex sheet material was prepared. This sheet was also confirmed to be as thin as less than 1 mm and gleam intensively in the dark when slightly bent. In the same manner, a cube of several mm each side was prepared by using a die, and stress emission spectrum appearing under compression was measured similarly to the first embodiment. As a result, broad emission spectrum having a peak near the wavelength of 520 nm was confirmed. Emission intensity of the emission peak near the wavelength 520 nm was two times or more as compared with that of the sample using $SrAl_2O_4$:Eu (Fig. 6).

[0064]

According to the fourth embodiment, it is possible to obtain $SrAl_2O_4$:Eu, Er as a novel stress emission material whose emission intensity is much higher by more than two times of the emission intensity of $SrAl_2O_4$:Eu that is a conventional stress emission material, and it is possible to ensure the same advantages as those of the first embodiment.

[0065]

Fifth embodiment

This embodiment is directed to a stress emission material composed of $SrAl_2O_4$:Eu, Gd and a complex material made of the stress emission material.

The stress emission material of this embodiment can be prepared in the same manner as the first embodiment except that gadolinium oxide (Gd_2O_3) is added as a Gd source

instead of a La source.

An X-ray diffraction pattern of the synthesized sample was measured, and it was confirmed that the sample was entirely indexed by the monoclinic system similarly to the known article (Non-patent Document 3) and that the major component was composed of crystals similar to those of the article (Non-patent Document 3).

[0066]

Similarly to the first embodiment, powder of $SrAl_2O_4$:Eu, Gd was next complexed with epoxy resin, and an inorganic/organic complex sheet material was prepared. This sheet was also confirmed to be as thin as less than 1 mm and gleam intensively in the dark when slightly bent. In the same manner, a cube of several mm each side was prepared by using a die, and stress emission spectrum appearing under compression was measured similarly to the first embodiment. As a result, broad emission spectrum having a peak near the wavelength of 520 nm was confirmed. Emission intensity of the emission peak near the wavelength 520 nm was as shown in Fig. 6.

[0067]

Sixth embodiment

This embodiment is directed to a stress emission material composed of $SrAl_2O_4$:Eu, Lu and a complex material made of the stress emission material.

The stress emission material of this embodiment can be prepared in the same manner as the first embodiment

except that lutetium oxide (Lu_2O_3) is added as a Lu source instead of a La source.

An X-ray diffraction pattern of the synthesized sample was measured, and it was confirmed that the sample was entirely indexed by the monoclinic system similarly to the known article (Non-patent Document 3)and that the major component was composed of crystals similar to those of the article (Non-patent Document 3).

[0068]

Similarly to the first embodiment, powder of $SrAl_2O_4$:Eu, Lu was next complexed with epoxy resin, and an inorganic/organic complex sheet material was prepared. This sheet was also confirmed to be as thin as less than 1 mm and gleam intensively in the dark when slightly bent. In the same manner, a cube of several mm each side was prepared by using a die, and stress emission spectrum appearing under compression was measured similarly to the first embodiment. As a result, broad emission spectrum having a peak near the wavelength of 520 nm was confirmed. Emission intensity of the emission peak near the wavelength 520 nm was as shown in Fig. 6.

[0069]

<u>Seventh embodiment</u>

This embodiment is directed to a stress emission material composed of $SrAl_2O_4$:Eu, Yb and a complex material made of the stress emission material.

The stress emission material of this embodiment

can be prepared in the same manner as the first embodiment except that ytterbium oxide (Yb_2O_3) is added as a source of Yb instead of a source of La.

An X-ray diffraction pattern of the synthesized sample was measured, and it was confirmed that the sample was entirely indexed by the monoclinic system similarly to the known article (Non-patent Document 3) and that the major component was composed of crystals similar to those of the article (Non-patent Document 3).

[0070]

Similarly to the first embodiment, powder of $SrAl_2O_4$:Eu, Yb was next complexed with epoxy resin, and an inorganic/organic complex sheet material was prepared. This sheet was also confirmed to be as thin as less than 1 mm and gleam intensively in the dark when slightly bent. In the same manner, a cube of several mm each side was prepared by using a die, and stress emission spectrum appearing under compression was measured similarly to the first embodiment. As a result, broad emission spectrum having a peak near the wavelength of 520 nm was confirmed. Emission intensity of the emission peak near the wavelength 520 nm was as shown in Fig. 6.

[0071]

Next explained is an artificial light-emitting hair structure according to the eighth embodiment of the invention.

First, polyester resin and powder of stress

emission material manufactured by any of the methods of the first to seventh embodiments are blended and mingled by the ratio of 1:2 in weight, and the resulting complex material is poured into a tube of an organic material such as nylon or polyetherimide while soaking it up with a syringe. After that, the tube containing the complex material is left for a whole day until it cures. This was employed as one of hair samples. These steps were repeated, and a required number of artificial light-emitting hairs were produced. The tubes used for the purpose may be nylon tubes having the outer diameter of 0.9 mm and the inner diameter of 0.5 mm or polyetherimide tubes having the outer diameter of 0.5 mm and the inner diameter of 0.3 mm. In this case, thickness of the complex material of each artificial light-emitting hair, which is composed of fine particles made of the stress emission material and the polyester resin, is equal to the inner diameter of the tube. That is, it is 0.5 mm or 0.3 mm, for example. The tube forming the investment of each artificial light-emitting hair functions to enhance the elasticity of the artificial light-emitting hair and protect the surface of the artificial light-emitting hair.

[0072]

Fig. 7 shows an artificial light-emitting hair structure comprising the artificial light-emitting hairs manufactured in the above-explained manner. Fig. 7A is its side elevation, and Fig. 7B is a plan view.

As shown in Fig. 7, the artificial light-emitting

hair structure includes artificial light-emitting hairs 12 fixed to stand from one of major surfaces of a substratum 11 at positions forming a square grid pattern. In this case, the substratum 11 has holes 13 in a square grid pattern, and roots of the artificial light-emitting hairs 12 are inserted in the holes 13 such that the artificial light-emitting hairs 12 stand on the substratum 11. For the fixture, an adhesive may be used, if necessary. The artificial light-emitting hairs 12 used here are manufactured as explained above. For obtaining a sufficiently flexible artificial light-emitting hair 12, diameter d of each artificial light-emitting hair 12 is preferably 2 mm or less in maximum, or more preferably 1 mm or less. For example, it is adjusted in the range from 0.3 to 0.5 mm.

[0073]

Material and thickness of the substratum 11 are determined adequately so that repetitive bending motion of the artificial light-emitting hairs 12 does not deteriorate the strength of fixture of the artificial light-emitting hairs 12 to the substratum 11, and taking account of the environments where the artificial light-emitting hair structure will be used. Especially, in case of an artificial light-emitting hair structure that will be affixed on a non-planar surface, the substratum 11 is preferably flexible enough to bend easily with a manual force of a person. For example, a resin film such as a polyester resin film is used.

Thickness of the substratum 11 is 2 to 3 mm, for example.

[0074]

The number of artificial light-emitting hairs 12 and their intervals are determined depending upon the intended use. In the example of Fig. 7, eleven hairs in each column and eleven hairs in each row, i.e. 121 hairs in total, are fixed. The interval a (see Fig. 7B) is determined such that the surface density of the artificial light-emitting hairs 12 is one piece per cm^2 or more. Typically, the interval may be 2 to 10 mm, for example. In this case, the surface density of the artificial light-emitting hairs 12 is 1 to 25 pieces per cm^2.

[0075]

Height h (see Fig. 7A) of the artificial light-emitting hair 12 is determined in accordance with sensitivities and tastes of users of the artificial light-emitting hair structure. Although the diameter d must be taken account, if a tactile impression similar to that of natural hair or an animal coat is desired to obtain when manually stroking the artificial light-emitting hair 12, the height h of the artificial light-emitting hair 12 is preferably two or three times the diameter d in minimum. Typically, the height h is 5 to 50 times the diameter d, for example. On the other hand, if a skin touch impression is desirable when manually stroking the artificial light-emitting hair 12, the height h of the artificial light-emitting hair 12 should be sufficient low. For

example, it may be lower than two or three times the diameter d. Extremely, the height h may be like a dot approximately equal to the diameter d.

[0076]

The inventors put the artificial light-emitting hair structure in the dark, and lightly stroked it with a fingertip. Then, the inventors could confirm that the artificial light-emitting hair 12 immediately emitted intensive light. After the inventors removed the finger stroke, the emission disappeared in a short time. While stroking the artificial light-emitting hair 12 and looking emission of light, the inventors felt that it stimulated their affections.

[0077]

According to this embodiment, the sufficiently thin artificial light-emitting hair 12 comprising an inorganic compound emitting light under a stress and a resin is manufactured, and a necessary number of artificial light-emitting hairs 12 are fixed to stand on one major surface of the substratum 11 in a square grid arrangement to make the artificial light-emitting hair structure. Therefore, a user can induce emission of light by lightly stroking the artificial light-emitting hair with his/her hand, and additionally, he/she loses the emission of light from sight immediately after removal of the stroke. Therefore, the user can enjoy not only a favorable tactile impression by stroking it, but also the emission of light

when he/she strokes it. This will be effective for consoling the user or improving the user's feeling.

This artificial light-emitting hair structure is suitable for use as artificial light-emitting skin. For example, it may be used to cover the surface of the body of a consolation robot, amusement robot, entertainment robot, or the like.

[0078]

Fig. 8 shows an artificial light-emitting fabric according to the ninth embodiment of the invention. As illustrated, this artificial light-emitting fabric is weaved or knitted by using artificial light-emitting fibers 21 as lengthwise threads and artificial light-emitting fibers 22 as fillings. The respective artificial light-emitting fibers 21, 22 used to weave or knit the fabric inevitably curve successively in a wavy form.

[0079]

The artificial light-emitting fibers 21, 22 used here are manufactured in the same manner as the artificial light-emitting hair 12 already explained. In order to obtain artificial light-emitting fibers 21, 22 flexible enough to weave or knit a fabric, diameter of the artificial light-emitting fibers 21, 22 is preferably 2 mm or less in maximum, more preferably 1 mm or less, and still more preferably 0.5 mm or less.

[0080]

Interval of the artificial light-emitting fibers

21, 22 is determined such that the artificial light-emitting fibers 21, 22 interlace preferably once or more per cm, or more preferably twice or more per cm. Typically, the interval may be 2 to 10 mm, for example. In this case, the interlacing period of the artificial light-emitting fibers 21, 22 is 1 to 5 times per cm.

Needless to say, as the artificial light-emitting fibers 21, 22 become thinner, and the interlacing period of the artificial light-emitting fibers 21, 22 become frequent, the artificial light-emitting fabric becomes denser. Thus, it will be possible to obtain a dense fabric equivalent to a true silk fabric.

[0081]

According to this embodiment, thin artificial light-emitting fibers 21, 22 are made from the composite material composed of an inorganic compound capable emitting light under a stress and a resin, and the artificial light-emitting fibers 21, 22 are used as lengthwise threads and fillings to weave of knit an artificial light-emitting fabric. Therefore, a user can induce emission of light from the fabric by lightly stroking the artificial light-emitting fibers 21, 22 with his/her hand, and furthermore, he/she loses emission of light from sight immediately after removal of the stroke. Therefore, although the fabric is not covered by hair, the user can get a favorable tactile impression when stroking it, and at the same time, and can enjoy emission of light. This will be effective for consoling the user

or improving the user's feeling.

[0082]

The artificial light-emitting fabric is suitable for use as artificial light-emitting skin. For example, it can be used to cover the surface of the body of a consolation robot, amusement robot, entertainment robot, or the like. It can be used to make clothes as well.

[0083]

Fig. 9 shows an artificial light-emitting fabric according to the tenth embodiment of the invention. Similarly to the artificial light-emitting fabric according to the twentieth embodiment, the artificial light-emitting fabric shown in Fig. 9 is also weaved or knitted by using artificial light-emitting fibers 21 as the lengthwise threads and artificial light-emitting fibers 22 as fittings. However, the artificial light-emitting fabric shown here is weaved or knitted in a different pattern. In the other respects, the features of the ninth embodiment are applicable here again.

The tenth embodiment also has the same advantages as those of the ninth embodiment.

[0084]

Fig. 10 shows an artificial light-emitting fabric according to the eleventh embodiment of the invention. Similarly to the artificial light-emitting fabric according to the ninth and tenth embodiments, the artificial light-emitting fabric shown in Fig. 10 is also weaved or

knitted by using artificial light-emitting fibers 21 as the lengthwise threads and artificial light-emitting fibers 22 as fittings. However, the artificial light-emitting fabric shown here is weaved or knitted in a different pattern. In the other respects, the features of the ninth embodiment are applicable here again.

The eleventh embodiment also has the same advantages as those of the ninth embodiment.

[0085]

Fig. 11 shows an artificial light-emitting fabric according to the twelfth embodiment of the invention. Similarly to the artificial light-emitting fabric according to the ninth, tenth and eleventh embodiments, the artificial light-emitting fabric shown in Fig. 11 is also weaved or knitted by using artificial light-emitting fibers 21 as the lengthwise threads and artificial light-emitting fibers 22 as fittings. However, unlike the preceding embodiments, here is used a substratum having periodical through holes 23 in an arrangement corresponding to the weaving or knitting period of the artificial light-emitting fabric, and the artificial light-emitting fabric is weaved or knitted while passing the artificial light-emitting fibers 21, 22 through the through holes 23. In the other respects, the features of the ninth embodiment are applicable here again. Also in this mode of weaving or knitting, the artificial light-emitting fibers 21, 22 used to weave or knit the fabric inevitably curve successively in a wavy form.

[0086]

The twelfth embodiment also has the same advantages as those of the ninth embodiment. Further, since this embodiment can make a weaving or knitting pattern of the artificial light-emitting fibers 21, 22 having a more accurate period, it has the additional advantage that the artistic aspect of the artificial light-emitting fabric can be improved.

[0087]

Having described specific preferred embodiments of the present invention with reference to the accompanying drawings, it is to be understood that the invention is not limited to those precise embodiments, and that various changes and modifications may be effected therein by one skilled in the art without departing from the scope or the spirit of the invention as defined in the appended claims.

For example, numerical values, structures, shapes, materials, source materials, processes, and others are not but examples. Other acceptable numerical values, structures, shapes, materials, source materials and processes may be employed alternatively.

[0088]

[Effects of the Invention]

As described above, according to the present invention, a novel stress emission material can be obtained by adding Eu and any of Ca, Ce, Er, Tm, Gd, Lu and Yb to a material expressed by $Sr_{1-x}Al_2O_{4-x-y}$ or $M_{1-x}Al_2O_{4-x-y}$.

Especially, the novel stress emission material containing any of La, Ce, Er and Tm in addition to Eu ensures remarkably high emission intensity. Further, if this stress emission material is complexed with a resin, for example, then a user can easily induce emission of light only by lightly touching it with his/her hand, for example. Moreover, it is possible to permit emission only when applying a stress by touching it, for example. From the complex material, artificial light-emitting hair and artificial light-emitting fiber can be manufactured, and from these products, it is possible to realize artificial light-emitting hair structures, artificial light-emitting skin, artificial light-emitting bodies, artificial light-emitting fabric, and so forth. These novel products will bring about a revolution in the field of robots for entertainment or amusement purposes and the field of optics, for example.

[Brief Description of the Drawings]

[Fig. 1]

Schematic diagram showing an X-ray diffraction pattern of a stress emission material prepared in the 1st embodiment of the invention.

[Fig. 2]

Schematic diagram showing stress emission spectrum of a stress emission material prepared in the 1st embodiment of the invention.

[Fig. 3]

Schematic diagram showing an X-ray diffraction

pattern of a stress emission material prepared as a comparative example in the 1st embodiment of the invention.

[Fig. 4]

Schematic diagram showing stress emission spectrum of a stress emission material prepared as a comparative example in the 1st embodiment of the invention.

[Fig. 5]

Schematic diagram showing stress emission spectrum of a stress emission material prepared in the 1st embodiment of the invention and a stress emission material prepared as a comparative example.

[Fig. 6]

Schematic diagram showing emission intensities of emission peaks near the wavelength 520 nm in stress emission spectra of $SrAl_2O_4$ added with Eu alone and $SrAl_2O_4$ added with Dy, Ce, Er, Gd, La, Lu, Yb or Tm in addition to Eu.

[Fig. 7]

Side elevation and plan view of an artificial light-emitting hair structure according to the 8th embodiment of the invention.

[Fig. 8]

Schematic diagram showing an artificial light-emitting fabric according to the 9th embodiment of the invention.

[Fig. 9]

Schematic diagram showing an artificial

light-emitting fabric according the 10th embodiment of the invention.

[Fig. 10]

Schematic diagram showing an artificial light-emitting fabric according the 11th embodiment of the invention.

[Fig. 11]

Cross-sectional view of an artificial light-emitting fabric according the 12th embodiment of the invention.

[Description of Reference Numerals]

11 ... Substratum, 12 ... Artificial light-emitting hairs, 21, 22 ... Artificial light-emitting fibers

[Title of Document] Abstract

[Abstract]

[Subject]

To provide a novel stress emission material whose emission intensity is higher than that of a known stress emission material.

[Solving Means]

A stress emission material is manufactured by adding Eu and any of La, Ce, Er and Tm to a material expressed by:

$Sr_{1-x}Al_2O_{4-x-y}$

where $-0.3<x<0.3$ and

$0 \le y < 0.2$

This stress emission material is complexed with a resin so that a complex material is manufactured.

[Selected Drawing] Fig. 6

Translation of Drawings

[FIG. 1]

(1)... INTENSITY

[FIG. 2]

(1)... STRESS EMISSION INTENSITY

(2)... WAVELENGTH

[FIG. 3]

(1)... INTENSITY

[FIG. 4]

(1)... STRESS EMISSION INTENSITY

(2)... WAVELENGTH

[FIG. 5]

(1)... STRESS EMISSION INTENSITY

(2)... WAVELENGTH

[FIG. 6]

(1)... STRESS EMISSION INTENSITY

(2)... ADDITIVE ELEMENT

[FIG. 7]

11 ... SUBSTRATUM

12 ... ARTIFICIAL LIGHT-EMITTING HAIR

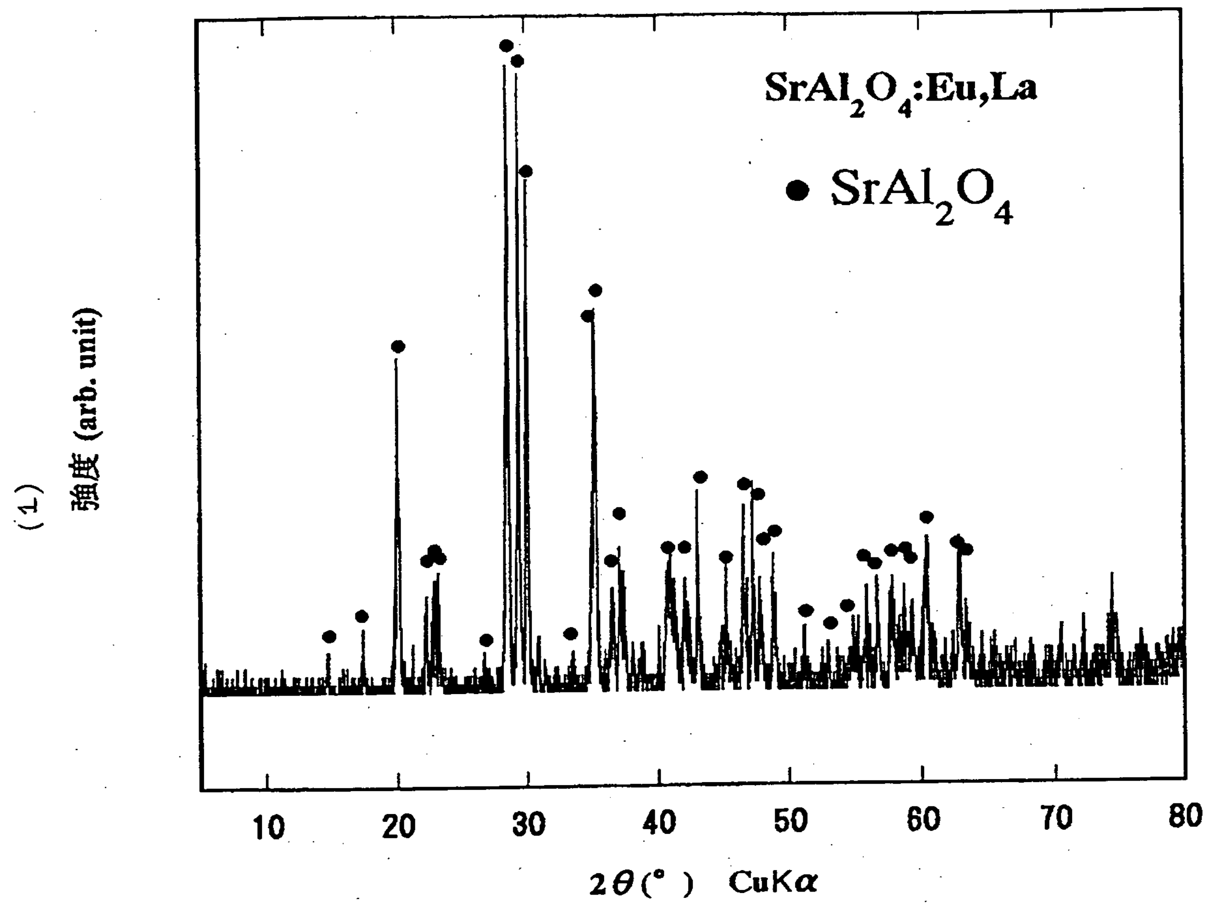
[FIG. 8]

21 ... ARTIFICIAL LIGHT-EMITTING FIBERS

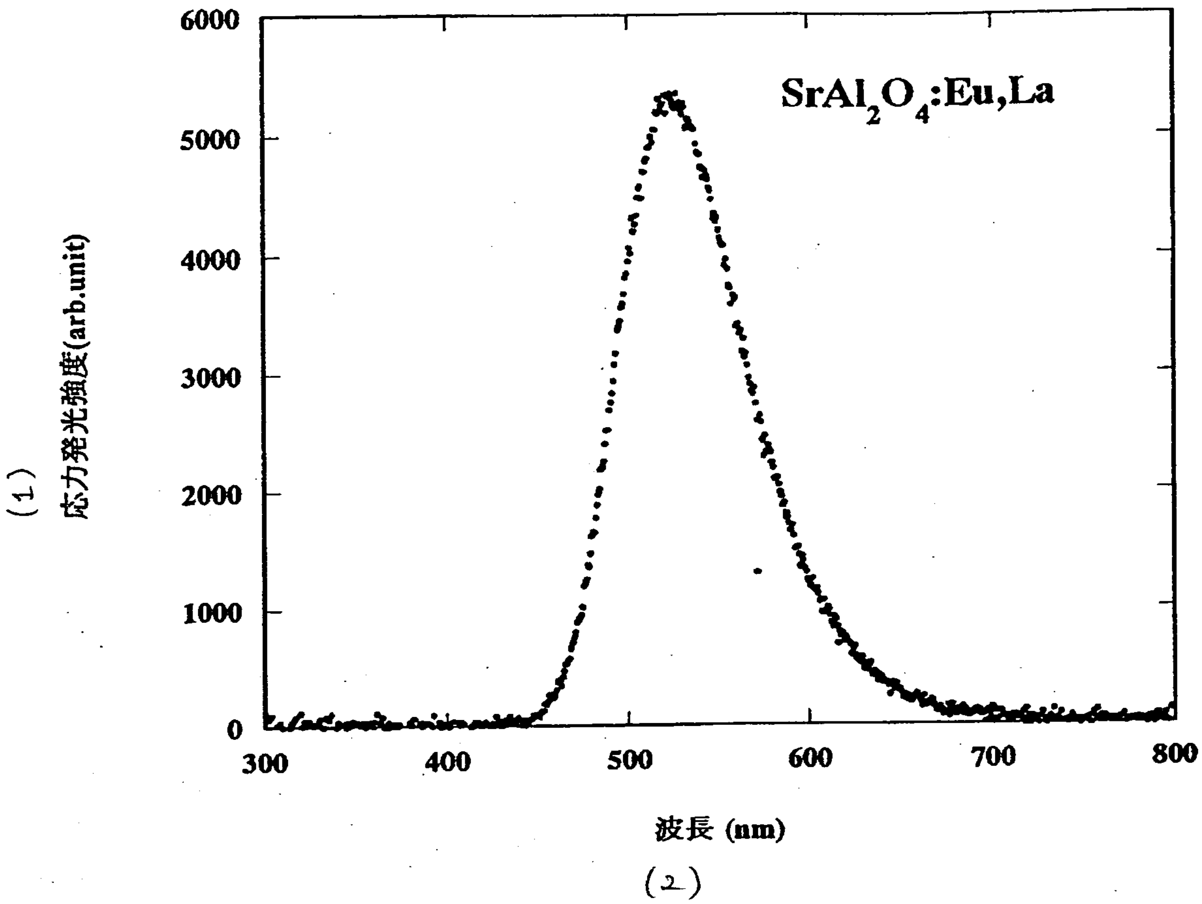
22 ... ARTIFICIAL LIGHT-EMITTING FIBERS

【書類名】　図面

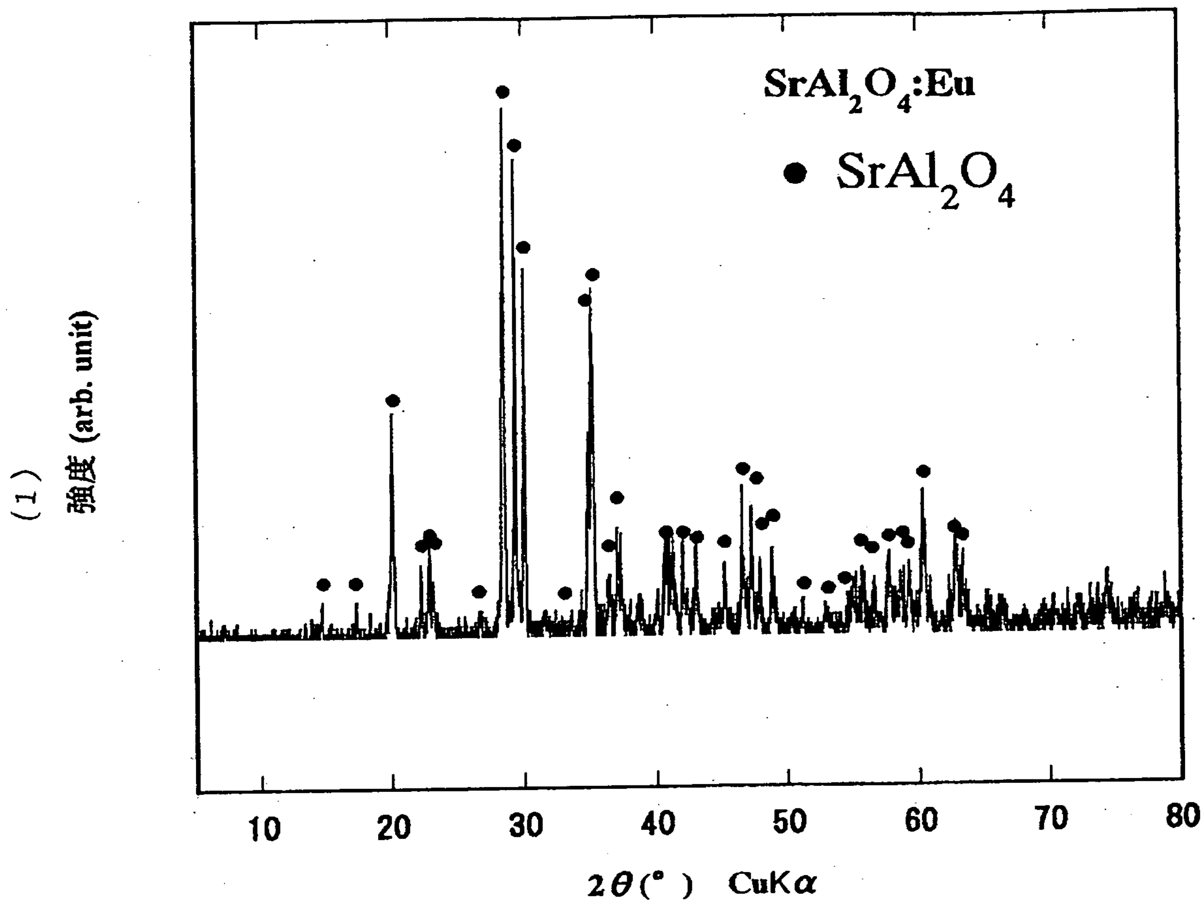
【図１】



【図２】


6000
5000
4000
3000
2000
1000
0
300
400
500
600
700
800
SrAl2O4:Eu,La
（１）
応力発光強度(arb.unit)
波長 (nm)
（２）

【図３】



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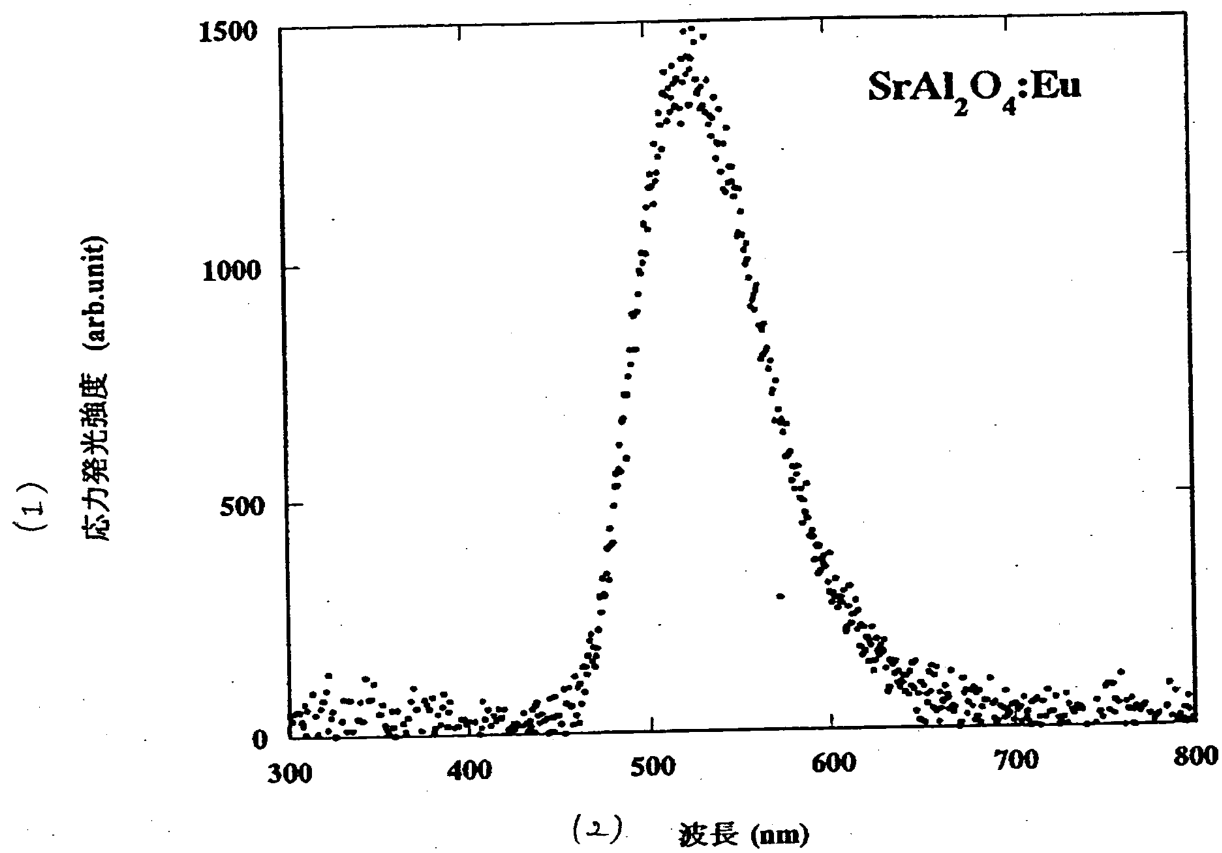
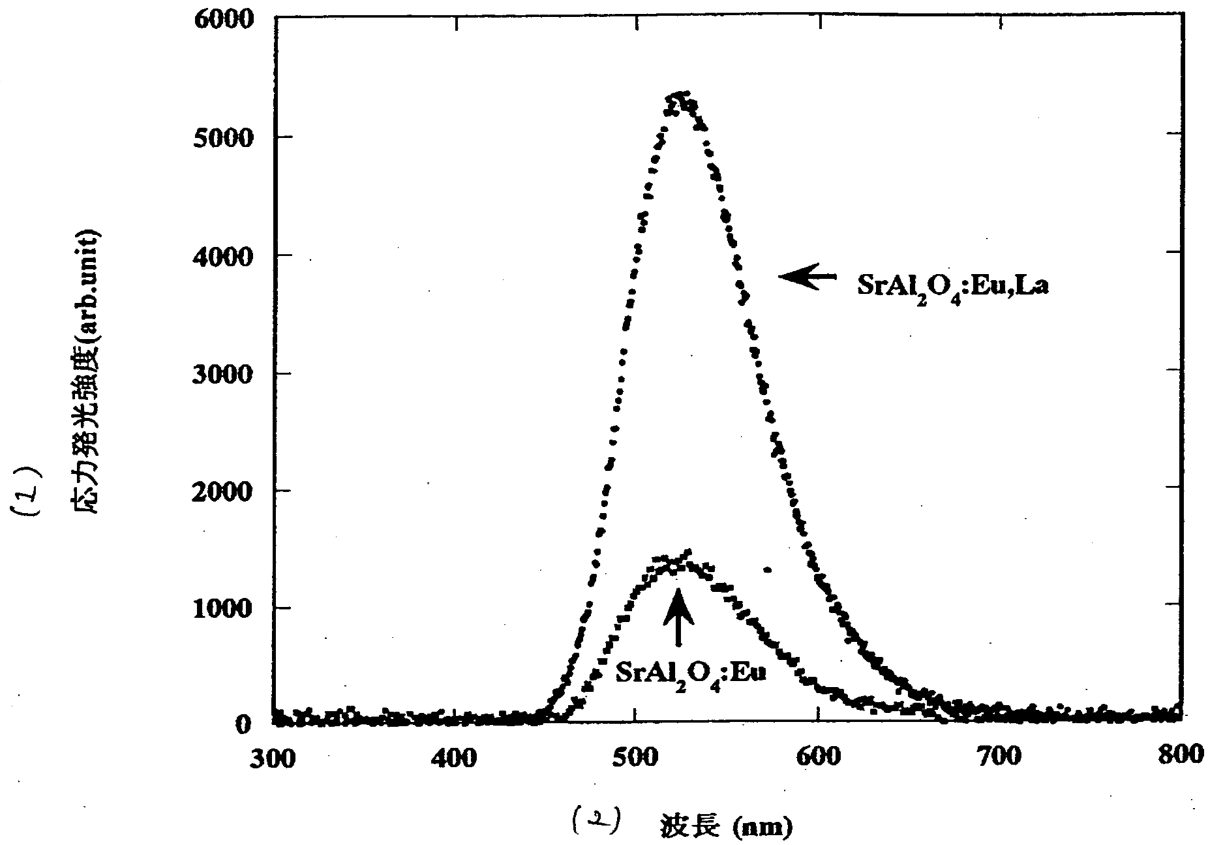


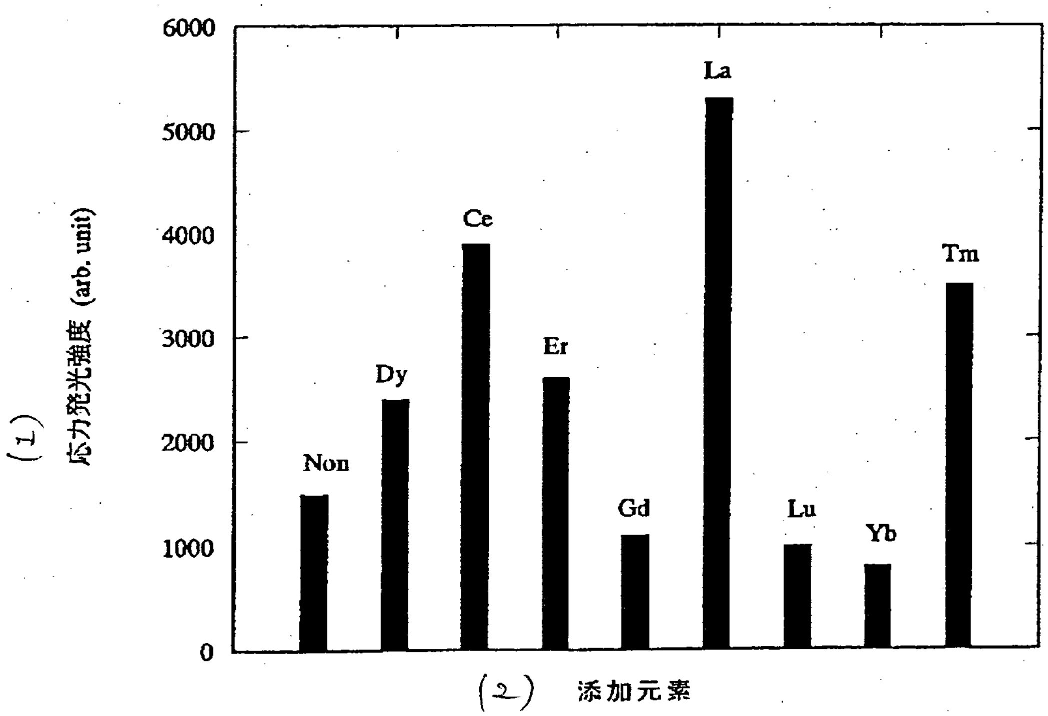
SrAl$_2$O$_4$:Eu
1500
1000
500
0
300
400
500
600
700
800
(1)
応力発光強度 (arb.unit)
(2)
波長 (nm)

【図５】



6000
5000
4000
3000
2000
1000
0
300
400
500
600
700
800
(1) 応力発光強度(arb.unit)
(2) 波長 (nm)
SrAl$_2$O$_4$:Eu,La
SrAl$_2$O$_4$:Eu

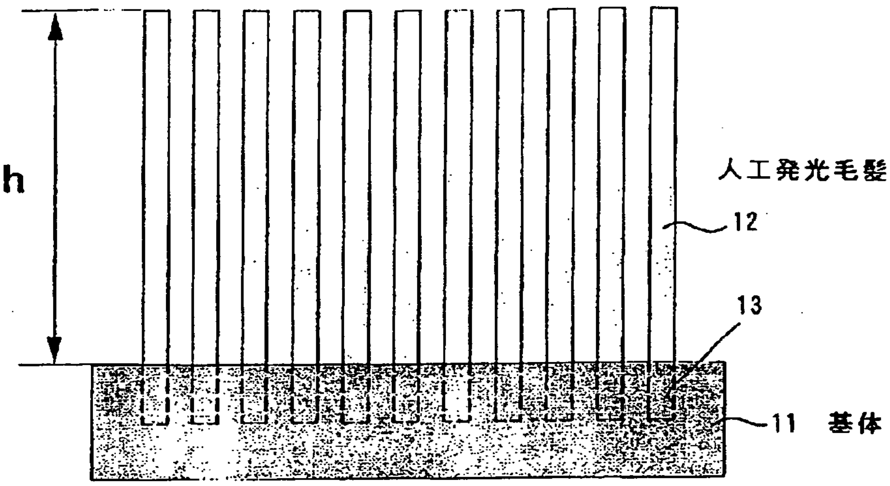
【図６】



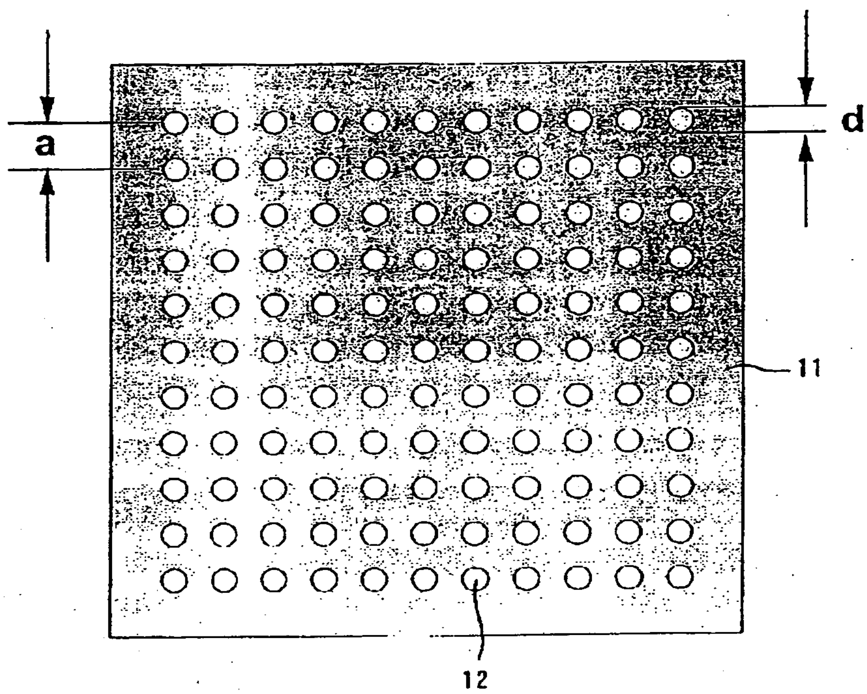
6000
5000
4000
3000
2000
1000
0
(1) 応力発光強度 (arb. unit)
Non
Dy
Ce
Er
Gd
La
Lu
Yb
Tm
(2) 添加元素

【図７】

A



B



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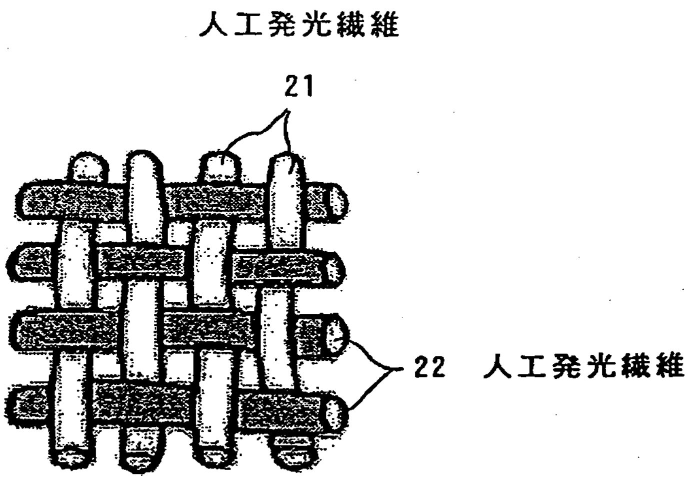

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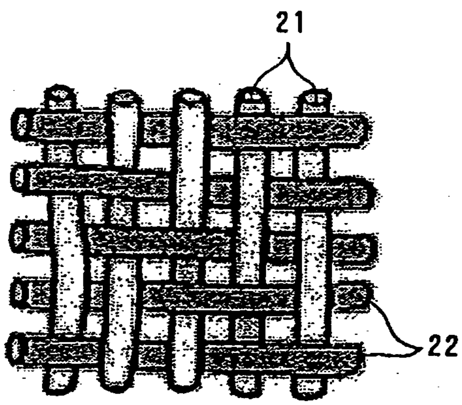
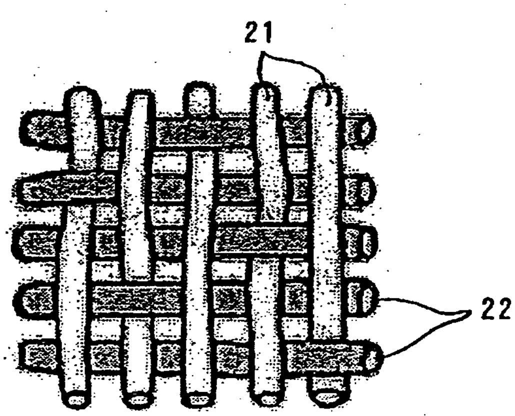


【図１０】



【図１１】